TWO GLACIAL STAGES IN ALASKA[1]

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The existing glaciers of Alaska are of such wide distribution and are such striking scenic features that they have attracted the attention of many glacialists. The coastal glaciers, many of which are of large size and relatively accessible, have been most frequently visited and described, and the literature on Alaskan glaciers now includes a large number of titles. The fact has been generally recognized by those who have studied the glaciation of this territory that the area at present covered by glaciers is much smaller than the area which was formerly covered by glacial ice, and glaciers no longer exist at many localities where the surface still shows conspicuous evidence of their former presence. This evidence consists of such physiographic features as typical glacial mountain valleys, U-shaped in cross-section; glacial lakes; moraines and hanging tributary valleys, and of such other evidence as is afforded by smoothed, polished, and striated rock surfaces; glaciated pebbles and bowlders; erratic bowlders, and deposits of glacial till.

It is beyond the scope of this paper to outline the areas in Alaska which are known to have been formerly covered by glacial ice. Brooks[2] published in 1906 a map showing the limits of glaciation, as known at that time. Tarr and Martin[3] have recently published a revision of Brooks's map, based on somewhat more recent information. On both of these maps a number of areas have been shown as glaciated about which no detailed information is available, and the outlines as given can be corrected only after much more field work has been done.

[1] Published by permission of the Director of the U.S. Geological Survey.

[2] A. H. Brooks, "Geography and Geology of Alaska," *U.S. Geol. Survey Paper 45*, 1906, Pl. XII.

[3] R. S. Tarr, and L. Martin, *Alaskan Glacier Studies*, National Geographic Society, 914, Map 1.

All attempts to map the limits of glaciation in Alaska have been made upon the assumption that the ice reached its greatest extension during the last great glacial advance, the evidence of which is so conspicuous, and that the limits of glaciation as shown are the limits reached by the ice during this period of expansion. Up to the present time no facts had been obtained which would show the age of this last great ice advance, as compared with any of the various stages of continental glaciation. Furthermore, although by analogy one might expect that the glaciers of Alaska would have been influenced by the same general climatic conditions which affected the main body of the continent, and would have advanced and retreated contemporaneously with the continental glaciers, yet for a period of fifteen years, during each summer of which geologists have been in the field observing glacial phenomena, the problem of whether or not there have been recurrent glacial stages in Alaska has continued to present many uncertainties. In 1890, and again in 1891, I. C. Russell[1] observed on the southern slopes of Mount St. Elias certain elevated marine deposits of fine clastic sediments containing bowlders which he believed to be of glacial origin. The same terrane was observed, in 1913, by A. G. Maddren[2] in the Yakataga district, and his interpretation of the origin of the bowlders is in agreement with that of Russell. The published literature for the most part, however, fails to discuss the probability of earlier stages of glaciation in Alaska, although the writer[3] has suggested that there may have been earlier glacial advances, but if so, they were less extensive than the last, and the traces of such glacial advances were destroyed or obscured by the more extensive and more recent ice invasion.

During a geologic reconnaissance trip into the White River basin, in the summer of 1914, observations were made which seem to throw light both upon the age of the last great ice advance and

[1] I. C. Russell, "An Expedition to Mount St. Elias," *Nat. Geog. Magazine*, III (1891), 170–73; also "Second Expedition to Mount St. Elias in 1891," *13th Ann. Rept. U.S. Geol. Survey*, Part II (1893), pp. 24–26.

[2] A. G. Maddren, "Mineral Deposits of the Yakataga District," *U.S. Survey Geol. Bull. 592*, 1914, pp. 131–32.

[3] S. R. Capps, "The Bonnifield Region, Alaska," *U.S. Geol. Survey Bull. 501*, 1912, pp. 35–36.

upon the problem of whether or not there have been recurrent glacial stages in Alaska. The first of these problems has been discussed elsewhere,[1] and the mere statement will suffice here that the last great ice advance was probably contemporaneous with the Wisconsin continental glaciation.

Near the source of White River in Russell Glacier and lying between Lime and Solo creeks, two of its tributaries, there are certain foothills of the mountains which in 1908 were seen by the writer to consist for the most part of gravels, but no careful study of this section was then made. In the summer of 1914 a

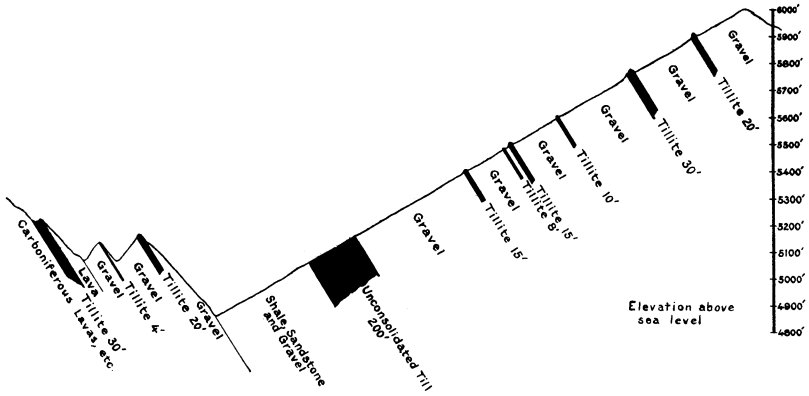

FIG. 1—Diagrammatic section of older glacial deposits near head of White River

single day was available in which to revisit this locality, and heavy rains and fog during that day prevented as thorough an examination as was desirable. The section shown in the accompanying figure (Fig. 1) is therefore not complete and the thicknesses given are only approximate, but nevertheless certain important facts are made clear. In the section to be described the exposure is unusually good, the surface of the hills being almost entirely free from vegetation, and cut by a number of clean, steep-sided gullies so that practically every foot of the deposit is exposed (Fig. 2).

The section, covering a vertical range of 1,150 feet, shows a great thickness of unconsolidated gravel beds, with some soft shales

[1] S. R. Capps, "An Estimate of the Age of the Last Great Glaciation in Alaska," *Jour. Wash. Acad. Sci.*, V, No. 4 (1915), 108–15.

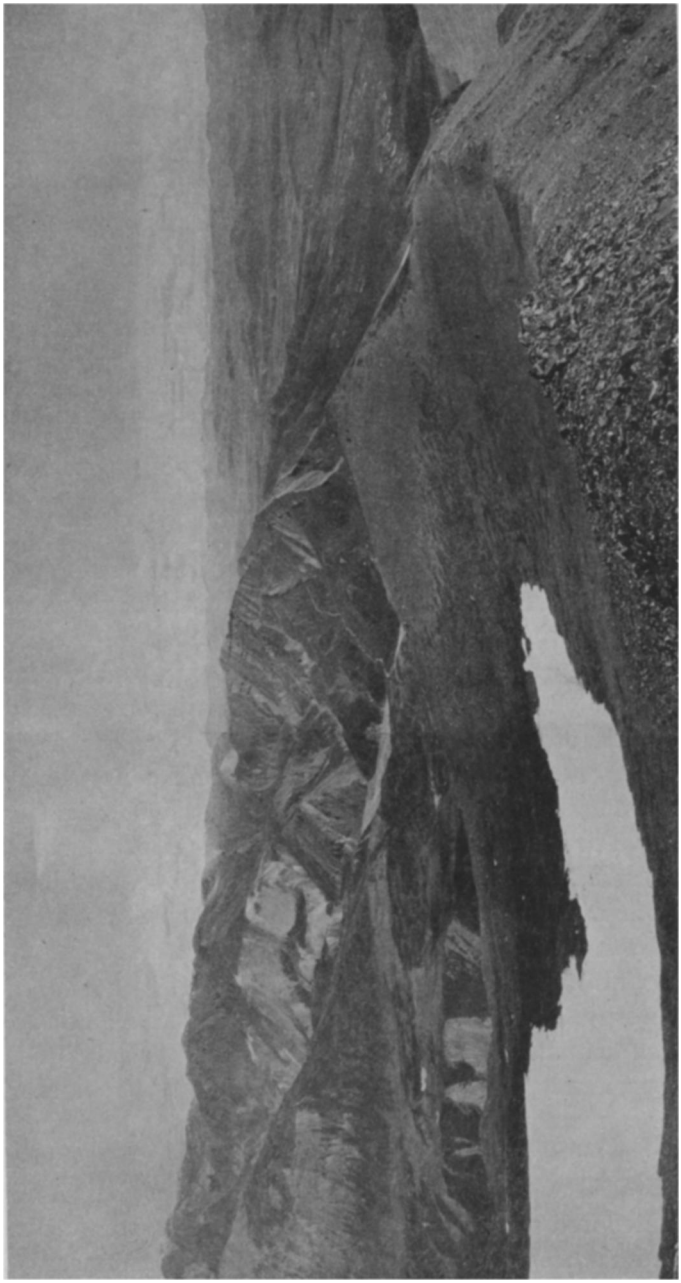

FIG. 2.—The older glacial deposits form the hill near the center of the picture. The lenticular beds, which project above the general slope, are lenses of tillite, separated by unconsolidated gravels and unindurated till.

and a little sandstone, interrupted by sheets and lenses of glacial till in varying stages of induration, and by lava flows. Measured perpendicular to the dip, more than 3,000 feet of beds were examined, and the thickness of the upward continuation of the series is not known, but is considerable. The gravels, which comprise much the greater part of the entire thickness, are well rounded but only fairly well assorted, and are apparently stream-laid. The pebbles are composed of the Carboniferous lavas and limestones which form the mountains immediately adjoining to the southwest. In one place a considerable thickness of arenaceous shales and sandstones occurs. Only one lava bed is shown in Fig. 1, but in other near-by localities similar lenticular lava flows were seen much higher in the section, and farther east, on North Fork of White River, the glacial series here described is overlain by lavas of considerable thickness.

The tillite beds, while forming only a small proportion of the whole series, are nevertheless the most conspicuous members of it, for their outcrops are left in high relief by the removal of the softer surrounding materials. The uppermost bed shown in the figure in places forms the crest of the ridge and stands up in high ragged pinnacles (Fig. 3). The tillite exactly duplicates, except for its induration, the ordinary glacial till which is of such widespread distribution throughout this general region. It has a clayey matrix full of small, angular particles of rock and incloses abundant pebbles, bowlders, and angular fragments of rock, many of which are several feet in diameter. The included bowlders and blocks are of the materials which compose the mountains to the southeast and are mostly of basic extrusive rocks of brown, purple, and reddish color, and the matrix has a slight purple tinge.

Striae were found abundantly on many bowlders, especially on those of fine texture. Large bowlders in particular showed plentiful striations, but typically striated hand specimens were not easily found. The characteristic subangular bowlders, so typical of glacial deposits, are plentiful throughout the tillite, and the whole aspect of these beds leaves no doubt of their glacial origin. A number of striated and subangular pebbles were broken from the hard matrix, and numberless other larger, but equally characteristic,

striated and subangular bowlders were found imbedded in it, so that no suspicion can be entertained that the glaciated bowlders were deposited upon the surface at this place by a later glacier.

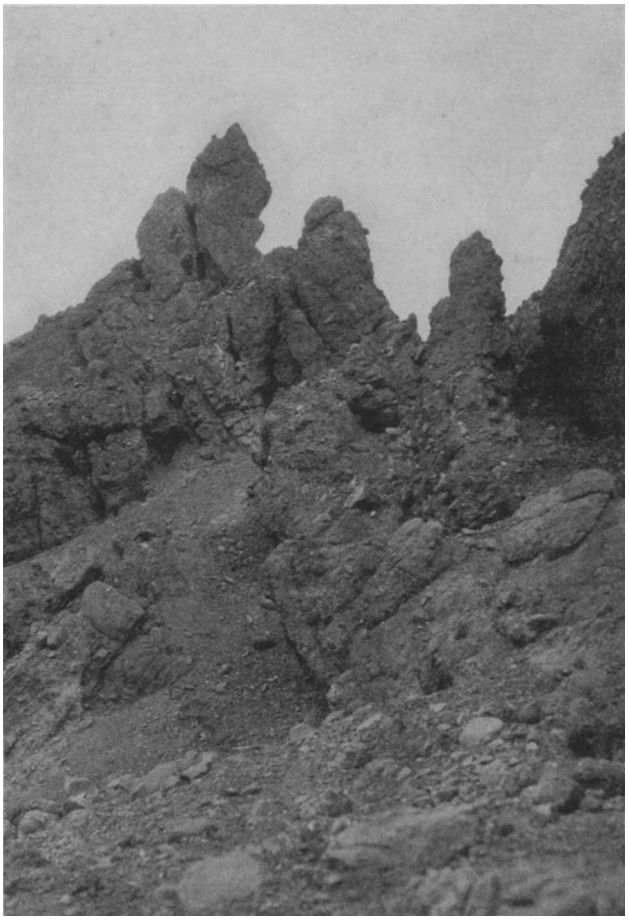

FIG. 3.—Close view of a tillite bed

In the particular part of the section measured, and shown in Fig. 1, there are nine beds of tillite, ranging from 4 to 30 feet in thickness, and one bed of uncemented glacial till, much covered by waste from above, but apparently at least 200 feet in thickness. Probably no other portion of the section would be like that figured,

for the tillite beds are lenticular in the cross-section exposed and probably also down the dip. The uppermost tillite bed shown is, however, known to persist along the strike for at least a mile, though its thickness is variable.

On North Fork of White River, about 6 miles east of the locality here described, similar tillite beds are exposed in the canyon of that stream and are there overlain by lava flows. The lava bed shown near the base of the section and other lava flows interbedded with the gravels and tillite higher in the series, but not at this particular place, are brightly colored, reddish, scoriaceous lavas, like the flows which are so generally distributed throughout the Wrangell Mountains. They range in age from Tertiary to Recent, and Mount Wrangell even now shows signs of mild activity.

As already stated, the evidence seems fairly definite that the last great ice advance in the White River valley was contemporaneous with the Wisconsin stage of continental glaciation. Till left by the ice during this advance is of widespread distribution in the White River basin, and wherever observed is unconsolidated and little oxidized. At one point at the edge of the Lime Creek gravel flat, about $2\frac{1}{2}$ miles from the locality of the section shown, the unconsolidated till of the last ice advance was found lying unconformably upon the upturned and glaciated edges of the older tillite, proving definitely that the tillite series was laid down during a glacial advance which antedated the last ice invasion. Furthermore, a long time-interval between the two glacial advances is indicated by the induration of the tillite and by its deformation since it was deposited. The physiographic evidence at hand also goes to show that the older tillite was indurated and uptilted and a mature topography eroded upon it before the last great glacier remodeled the surface and left its morainal deposits.

The tillite series here discussed is thought to have been laid down near the oscillating edge of a glacier. The record shows repeated advances, with deposits of morainal material, followed by recessions during which the till was covered by outwash gravels from the ice front, and one period during which finer sediments, represented by the shales and sandstones, were laid down. These materials may represent lake deposits. There were also occasional

extrusions of lava over the surface of till and outwash. The lenticular shape of the tillite beds may be due either to the shape of the original morainal beds, or to local erosion following a time of ice recession. The lack of induration of one thick till bed may have been due to the impenetrability of the till itself, or of the underlying shale, and is not believed to affect the general interpretation of the section. The whole series of beds, with the exception of the lava flows, is probably similar to the deposits now being laid down near the terminus of many a glacier in this same mountain range.

Little can now be said of the areal extent of the glacier which left these old morainal deposits. The elevation of the present exposures is of little importance, for the beds show by their structure that they have been tilted, with minor folding, and their present elevation may be much different from that at which they were laid down. At present the 3,000 feet of the beds described are seen within a vertical range of only 1,150 feet. The beds at this locality dip from 55° to 60° to the east, but the dips gradually become less as the distance from the mountains increases, and as seen in the canyon of North Fork of White River the tillite is nearly flat-lying. All the known outcrops of tillite lie well within the limits reached by the ice during its last great advance, and no comparison can yet be made of the extent of the ice fields during the two stages.

Summary.—There have now, for the first time, been found in Alaska deposits of glacial till which can be proved to antedate by a considerable period of time the last great ice expansion, thus proving that there have been at least two distinct glacial stages in that territory. The deposits comprise a series having a thickness over 3,000 feet and consist of indurated as well as unconsolidated glacial till sheets, separated by outwash gravels and some assorted sediments, and interrupted by lava flows. The section examined was evidently deposited near the border of an oscillating ice edge and shows ten definite advances of unknown magnitude, represented by the deposition of till beds, followed by periods of retreat during which water-laid beds were deposited upon the successive till beds. After its deposition this series of glacial and glacio-fluvial beds was covered by lava flows, at least locally, was uplifted, in part indurated, and was later deeply cut by erosion. A much later ice

advance, probably contemporaneous with the Wisconsin continental glaciation, then took place, overriding the earlier glacial deposits and locally capping them with later till beds. The extent of this earlier glacial advance, as compared with the last great stage of glaciation, is not known, all of the observed deposits of older glacial material lying far within the outer limit of the last great glaciation. Enough data have not yet been obtained upon which to base a correlation of the older glacial deposits with the earlier stages of continental glaciation.